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20 ABSTRACT (Continue on reverse side if necessary and identify by block number)

A unique set of data were compiled and analyses ~~based thereon~~ were prepared in support of the Environmental Definition Program (EDP) effort conducted by the ~~Meteorology Laboratory of the Air Force Cambridge Research~~ Laboratories (AFCRL). This data set formed the basic input to the AFCRL second generation model (AFCRL II) which was used to derive a climatology of liquid water content profiles and hydrometeor distribution at selected U.S. and Eurasian locations. The data set consists of conventional and meteorological data (surface and upper air);

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DMSP satellite imagery; Air Force Global Weather Central's three-dimensional nephanalyses; time-height cross section analyses of temperature, moisture, stability fields; inferred cloud and hydrometeor fields; and cloud nephanalyses based on the DMSP imagery. Approximately 4000 time-height cross sections and 1450 satellite nephanalyses were prepared for the period between 1 February 1973 and 30 January 1974. This report describes the technique used for the preparation of these analyses. Assignment of the final liquid water content values and hydrometeor distributions was accomplished by AFCRL meteorologists; these results are contained in reports prepared at AFCRL and are not contained herein.

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1. INTRODUCTION

Under contract F19628-74-C-0073, Environmental Research & Technology, Inc., provided technical assistance to the Meteorology Laboratory of the Air Force Cambridge Research Laboratories (AFCRL) for the following tasks:

a) preparation and analysis of time-height cross sections of meteorological parameters using data obtained from selected Eurasian stations, from the Wallops Flight Center, Virginia, and the Kwajalein Missile Range (KMR), Marshall Islands

b) analysis of satellite imagery coincident with the cross sections

c) development of data display techniques for the AFCRL Liquid Water Content Analyzer

d) general data processing and programming support.

The analyses and computer processed data were used by meteorologists at AFCRL to derive liquid water content profiles and hydrometeor distributions at selected locations, and to characterize cloud and precipitation systems during certain tests and experiments conducted at Wallops Flight Center and at Kwajalein.

In addition to the work discussed in detail in this report, special software was developed and implemented on the AFCRL Liquid Water Content Analyzer (LWCA). This latter device is a computer-driven color display system designed to work with weather radar data. The software developed under this program was designed to process and convert the radar signals and display, in a color-coded scheme, the information in terms of liquid water content values. The LWCA was on-site at Wallops Flight Center assisting the special flight measurements. Other computer programs developed were designed to perform processing and analysis of the weather radar data from Kwajalein. These programs were implemented on the AFCRL computer facilities.

The major portion of this report will focus on the unique set of data and analysis products developed under this study to establish a climatology of clouds and precipitation over selected stations in the

USSR. These products form the basic data input to the AFCRL second generation model (AFCRL II) from which hydrometeor distribution and liquid content profile values were deduced. The format of the report is as follows. In Section 2, a brief discussion is presented summarizing the stations, data, and period of record selected for analysis. The approach used in the analysis is provided in Section 3, and illustrative examples are shown in Section 4. Conclusions and recommendations are presented in Section 5.

2. DATA SAMPLE

2.1 Station Locations

Eleven stations were selected by AFCRL for the Environmental Definition Program (EDP) as being representative stations to obtain a climatology of cloud and precipitation parameters over the USSR. These stations and their geographical locations are given in Table 1 and in Figure 1. All of the stations are to the west of 130°E,

TABLE 1

LOCATION OF THE ELEVEN EDP STATIONS

Station Name	Lat.	Long.
Murmansk	68°58' N	33°03' E
Leningrad	59°58' N	30°18' E
Moscow	55°58' N	37°25' E
Kiev	50°24' N	30°27' E
Simferopol	45°01' N	33°59' E
Perm	58°01' N	56°18' E
Aktyubinsk	50°20' N	57°13' E
Semipalatinsk	50°21' N	80°15' E
Tashkent	41°16' N	69°16' E
Chita	52°01' N	113°19' E
Blagoveshchensk	50°16' N	127°30' E

with most of the stations concentrated in European USSR. Other stations analyzed on a less extensive basis were the Wallops Flight Center and the Kwajalein Missile Range. The analysis techniques used were the same in all cases.

2.2 Period of Analysis

A minimum analysis program for the selected stations within the USSR was undertaken, using one year of data for each of the eleven stations. The twelve months from 1 February 1973 to 31 January 1974 were selected because of the expected availability of continuous

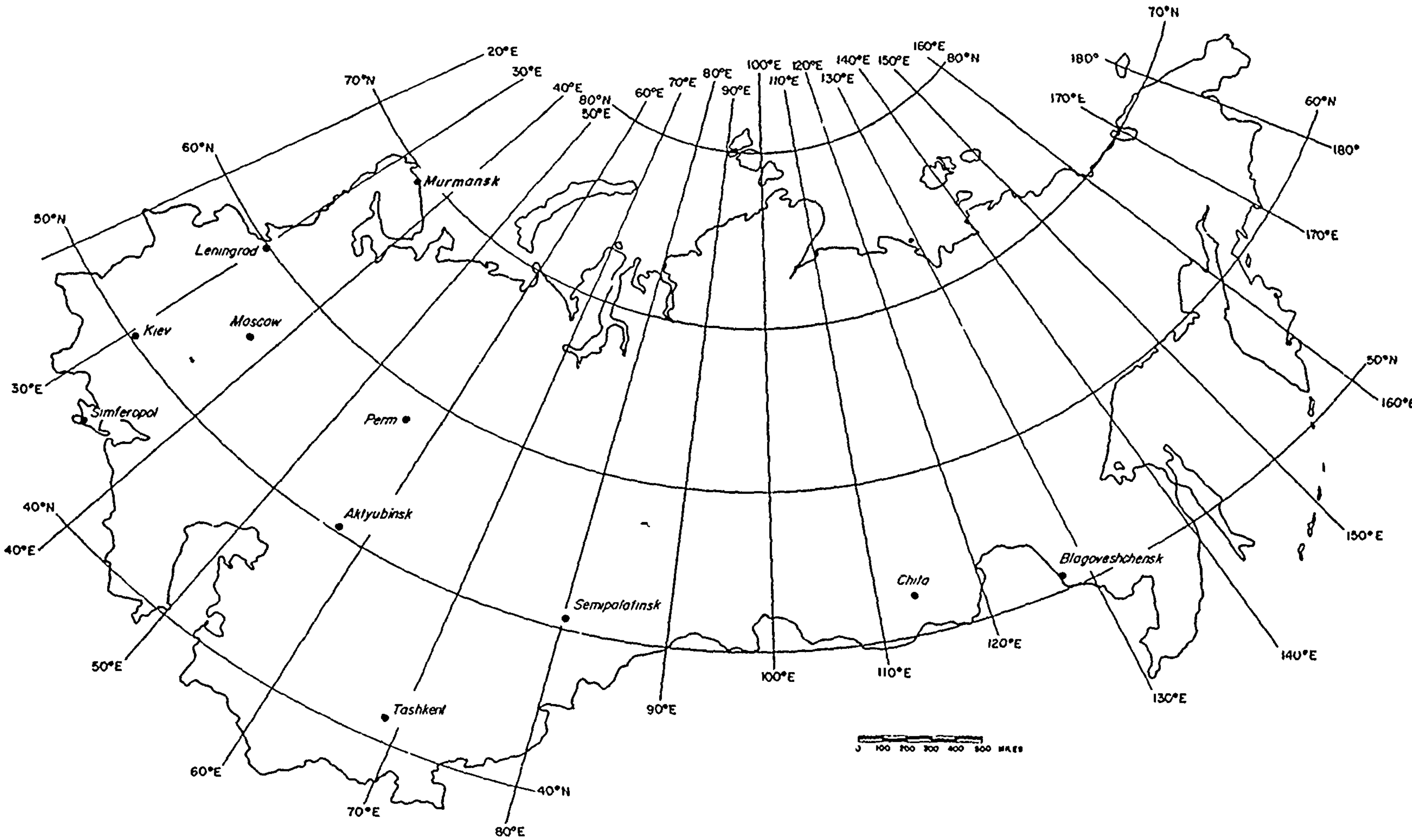

Figure 1 Map Showing Spatial Distribution of Stations Selected for Analysis

meteorological satellite data coverage. As the vertical profiles were produced on a three-hourly basis for each station, approximately 32,000 profiles were generated from these analyses. The Wallops Flight Center and KMR data covered individual storm cases over the period of the contract.

2.3 Raw Data

The time-height cross section analysis approach required inputs of all systematically available meteorological data. The data provided to, or acquired by, ERT and used in the plotting and analysis of the time-height cross sections are summarized in Table 2. The AFGWC 3DNEPH is a special product provided by AFGWC, through ETAC, which specifies cloud data at each of 15 levels, and at regularly spaced grid points 25 nautical miles apart. The data are arrived at using a logical decision tree procedure applied to conventional and satellite data. The details of the procedure are described in two reports by Coburn (1970 and 1971).

TABLE 2

SUMMARY OF DATA USED IN ANALYSIS

Date Type	Data Format	Frequency	Source
Surface Synoptic Reports	Coded Printouts	3-hourly	ETAC[1]
Upper Air Reports (RAOBS)	Coded Printouts	6-hourly	ETAC
Northern Hemisphere Surface Maps	Reproduced Maps	12-hourly	ETAC
AFGWC 3DNEPH[2]	Coded Printouts	3-hourly	ETAC
DMSP[3] Imagery	Positive Transp/ Positive Prints	Daily	U. Wiscon./ AFGWC

[1]ETAC - Environmental Technical Application Center

[2]AFGWC 3DNEPH - Air Force Global Weather Center Three-Dimensional Nephanalysis

[3]DMSP - Defense Meteorological Satellite Program

The visual DMSP satellite images, for the period prior to 1 November 1973, were obtained on loan from the University of Wisconsin in the form of archived positive transparencies. Positive prints, at full scale, were prepared from these transparencies for segments of orbits over the analysis area*. The original transparencies were returned to the University of Wisconsin, and the positive prints retained as part of the data base. Satellite imagery for the remaining months were acquired from AFGWC through AFCRL. Positive prints for these orbits have also been retained in the data base.

*The orbits over the areas of interest usually occurred near the local noon.

3. ANALYSIS

3.1 Objective and Rationale

The primary objective of the analysis was to provide the essential meteorological information in a time-height cross section format from which cloud and hydrometeor parameters could be inferred using the AFCRL second generation model (AFCRL II) as described by Cunningham and Peirce (1974). The underlying assumption is that the analysis of the vertical structure of temperature and moisture, when interpreted with concurrent surface reports, should provide a good estimate of the vertical distribution of clouds and hydrometeor parameters. Satellite data, in the form of DMSP imagery, were also used to assist in defining the cloud field.

3.1.1 Temperature Analysis

Danielsen (1959) and Browning et al. (1974), among others, have shown that the structure of the atmosphere is basically layered. Discontinuities such as frontal systems and subsidence inversions seem to be best described as discontinuities of the first order, i.e., discontinuities in the gradients of a variable rather than in the variable itself.

Stable and conditionally unstable layers are linked with the cloud pattern through the following conditions. First, stable layers act as a brake on vertical motions, such as those producing cumulus type convection. Such layers are assumed to be ceilings on the tops of most clouds. The tropopause (located at the minimum temperature of a sounding) is a very strong lid on the vertical development of most cloud masses.

Stable layers may originate as extrusions of stratospheric air near the dividing line of strong cyclogenic and anticyclogenic areas. Large scale subsidence will enhance any discontinuities in stability that may be present and dry out air that was originally moist. Hence, the presence of several stable layers with unstable layers in between indicates widespread descending motion and the air in that region is unusually dry. However, stable layers are not necessarily always dry.

The set of data studied include winter situations, where cold air cannot contain much water vapor. The rates of release of latent heat of condensation and evaporative cooling are generally small in this case. Hence, originally dry, stable layers may become saturated, depending upon how much precipitation evaporates in them, without becoming appreciably colder or more unstable. Therefore, in the absence of differential advection and strong, large scale ascending motion, cold precipitation cloud masses are more likely to contain saturated stable layers than are the warmer clouds.

Conditionally unstable air often contains convective clouds, particularly where there is also slow, large scale ascent. Precipitation from these clouds can seed underlying, supercooled cloud decks or even air which is saturated with respect to ice and is relatively clear. This situation tends to produce the snow showers that were noted in many of the profiles.

3.1.2 Humidity Distribution Analysis

Humidity is given in the upper air reports as the dewpoint depression below ambient temperature. The dewpoint depression is almost linearly proportional to the pressure interval over which the air must be lifted before condensation starts and, hence, is a good measure of the likelihood of rapid cloud formation. It is arbitrarily assumed here that air with a dewpoint depression of 3°C or less in winter already contains broken to solid clouds, and that clouds are very unlikely at dewpoint depressions greater than 7°C.

Experience has shown that the Russian radiosonde humidity element exhibits a significant lag under certain conditions. The element used is an organic membrane which is fairly delicate and can have a very long response time, on the order of several hundred seconds under certain conditions. Thus, should the sonde pass through a fairly deep, solid cloud layer and the element become saturated, it will continue to indicate saturated conditions for a considerable distance above the cloud tops. The sonde may have covered several hundred meters in altitude before it begins to dry out enough to no longer indicate saturated or moist conditions. Therefore, care must be exercised during the analysis procedure not to place the cloud tops higher than they actually are; other data must be examined to make certain that the analysis is correct.

3.1.3 Prediction of the Cloud Structure on the Basis of Temperature and Humidity Analyses and Surface Reports

Generally, clouds will be confined to near-saturated air and rather moist, conditionally unstable layers, whereas dry and stable layers are highly unlikely to contain any clouds at all. Hence, the following assumptions are made:

1) The tropopause acts as an upper boundary to most cloud decks. Where breaks in the tropopause occur, due to intrusions of warm tropospheric air, this may not be strictly true; however, any clouds present in the stratosphere are extremely tenuous, except when they represent the tops of large cumulonimbus. In the majority of cases, according to the Russian literature, cloud tops at the upper levels tend, on the average, to be about 1,400 meters below the tropopause. In our analysis, therefore, we have taken the cloud tops to occur at the point where the temperature lapse rate below the tropopause becomes less steep rather than at the top of the inversion which marks the tropopause itself.

2) Where surface observations indicate clear skies, no clouds are entered.

3) Where continuous precipitation is observed, solid cloud is assumed up to where the dewpoint depression becomes 3°C or more. Above this deck, scattered to broken clouds are assumed where the air is conditionally unstable and the dewpoint spread is less than 7°C.

4) Conditional instability and relatively small dewpoint depressions above a dry, stable layer indicate the possibility of the occurrence of cumuliform clouds which may act as seeder clouds.

3.1.4 Satellite Data Analysis

Another source of information on cloud and hydrometeor systems is the meteorological satellite. During the period of analysis, nearly continuous cover over the Eurasian stations was provided by the DMSP satellite. This satellite was in sun-synchronous orbit with local passage over the stations occurring near local noon and midnight. Two sensors on board the satellite are of particular importance to mapping the spatial extent and character of the cloud field. These are the two scanners - one operating in the visible portion of the spectrum and the other in the thermal infrared. The visible scanner provided high resolution depiction of the cloud field during the daylight portion of the orbit, while the infrared scanner provided both day and night coverage at a coarser resolution.

Since the launch of the first meteorological satellite, TIROS I, standard techniques have been developed to produce nephanalysis from satellite imagery. These techniques are based on the relationship between the "brightness" or gray tones depicted in the satellite imagery and the characteristics of the cloud field. Very simply stated, the underlying assumption is that in the visible scanner imagery, very thick clouds appear white. Thinner clouds appear in grayer shades. Stratiform clouds show uniform texture, while convective clouds are characterized by a high degree of variability in gray tones. In the infrared imagery, high (and therefore, cold) clouds appear white. Low (and therefore warm) clouds appear in darker or grayer tones.

Beyond these primary interpretative keys, secondary keys are also used to identify the cloud type depicted in the imagery. These secondary keys are dependent on the overall pattern of the cloud field and the location of the specific cloud mass relative to the overall pattern. These keys are described in the literature (e.g., Widger, et al., 1964).

Despite the extensive application of satellite imagery in nephanalysis, there are uncertainties. The most important of these result from the lack of contrast between clouds and snow in both the visible scanner imagery and in the infrared scanner imagery. Another uncertainty of importance is location. Geographic gridding of the imagery is often imprecise, resulting in location errors. With care, and using identified geographical landmarks, these errors can be minimized.

In summary, the satellite imagery data can provide depiction of the horizontal extent of cloud coverage and often a good estimate of the types of clouds over a given location, at least as viewed from above. In this regard, the data complements the surface observations which provide reports of the cloud field as seen from below.

3.2 Plotting and Analysis Procedure

3,2.1 Time-Height Cross Sections

Time-height cross sections were separately prepared for each of the eleven stations for all days except for those days when surface reports indicated clear sky conditions. The plotted data include surface observations of:

present and past weather

precipitation (type and amount)

sky cover

cloud type and amount

wind speed and direction

temperature

dew point

pressure

pressure change and tendency

and upper air observations of:

temperature

dewpoint depression

wind speed and direction for the mandatory and significant levels.

Isotherms were drawn at 5°C intervals. Temperature inversions were analyzed and, where appropriate, linked temporally over a number of soundings. Moist and dry layers were analyzed on the basis of dewpoint depression. It was assumed that air with a dewpoint depression of 3°C or less contained broken or solid clouds, and that air with a depression greater than 7°C is unlikely to contain clouds. Superimposed on these basic analysis is the analysis of stable and conditionally stable layers.

The inferred cloud field was entered onto the time section analysis. As a final check, the cloud data were compared with the corresponding nephanalysis prepared using the visual DMSP satellite imagery. The results of these analyses is a set of time-height cross sections, one for each station-day, containing both raw and analyzed data. These time sections were used by AFCRL to derive the liquid water content values and hydrometeor distribution profiles at each three-hour interval.

Using the time cross-section analyses, precipitable water values were computed for four layers of the atmosphere for each sounding. The layers selected were 1,000-700 mb, 700-500 mb, 500-400 mb and 400-300 mb. In each layer, all available pressure level data were examined, and levels which weighted the layer towards unrealistic computations were eliminated. Dew point temperatures were computed for the remaining levels from the temperature and dew point depressions given by the sounding and converted to mixing ratio values (g/kg). An average of these mixing ratios was then found for each layer and converted first to precipitable water in cm; then to precipitable water in g/m^3. Saturated mixing ratios over water and over ice, and their difference (S.M.I.-S.M.W.) in g/m^3 were also computed for the pressure levels of 1,000, 700, 500, 400 and 300 mb for all temperatures less than 0°C.

3.2.2 Nephanalysis

Nephanalyses, for each day, were prepared using the DMSP imagery. The analyses were performed on positive prints. Each frame was first carefully gridded, using a grid provided by AFCRL. The geographic referencing was further refined by locating specific geographic features in the imagery such as coastlines, mountain ranges, lakes and other readily identifiable features. The locations of the stations were then noted on the imagery.

The extent of cloud cover, and the shape of the cloud cover pattern was then mapped from an analysis of the gray and white patterns in the imagery. Cloud cover amounts, in octas, and cloud type were then entered where appropriate. The result is a geographically referenced nephanalysis of the instantaneous cloud field corresponding to the time of satellite passage. These nephanalyses were then used to refine the time-height cross section analysis where appropriate.

3.2.3 Comparison of the Time-Height Cross Sections with the AFGWC Three-Dimensional Nephanalysis

Subsequent to plotting and analyzing the available meteorological data, the AFGWC three-dimensional nephanalysis (3DNEPH) for the grid point(s) closest to the station under examination was entered on the map for the proper time-height intervals. A comparison of the two analyses could then be performed. In doing this, however, certain points concerning the manner in which both analyses were prepared must be kept in mind. In the first place, the analyzed time-height cross section represents a two-dimensional slice of the vertical structure of the atmosphere as it passes over a station. A problem can arise with weather systems which do not move, but only change with time. This fact often cannot be gleaned from the time-height cross section for a single point; only that part of the changing system which is actually over the station and its change with time can be studied.

The 3DNEPH program estimates the percentage of cloud (volume and area coverage combined) present at each grid point (25 nm apart over the entire hemisphere) for fifteen levels in the atmosphere. Each of the fifteen layers varies in thickness, increasing from the bottom layer (150 feet thick) to the top (15,000 feet thick). Basically, the data upon which the vertical profile is built for each point is obtained by shifting the conventional meteorological data from each observation point to the nearby grid-points, employing a smoothing and weighing process to do this. The satellite data, which also undergoes an analyzing and weighing process, is not required to be shifted in any way. Therefore, the manner in which the 3DNEPH is arrived at makes a valid one-to-one comparison with the hand-analyzed cross section very difficult to perform. The degree to which the two analyses agree is almost directly related to the relative locations of the chosen grid point and the density and location of nearby observation points. For example, the amount of data available around the Moscow area and the closeness of the nearest grid points to the observing locations yield fairly good correlation between the two analyses. For some of the other areas, particularly at the higher latitudes where the low sun angle during the winter months makes the satellite analysis much more difficult to perform, the correlation may often be rather poor.

3.3 Liquid Water Content Profiles and Hydrometeor Distributions

Liquid water content profiles and the hydrometeor distributions were derived from the completed meteorological analyses described above using the techniques detailed by Cunningham and Peirce (1974). Cloud boundaries, ice crystal (IC) areas, small snow (SS) areas and large snow (LS) areas were delineated. The cloud boundaries were initially established from information on cloud bases and types as reported by the ground observer and from the moisture boundaries. Cloud tops were placed with reference to the moisture boundaries and to the stable layers or by reference to the usual thicknesses for the type(s) observed. At the time of the satellite pass, major guidance on the cloud structure was obtained from the nephanalysis of the satellite photographs. The cloud amounts were determined by reference to the observed amount (low types only), to the reported total sky cover, to the moisture patterns and to the satellite photographs when available.

Liquid water content values were assigned in part by reference to the average values (e.g., A.M. Borovikov et al., 1961). Other factors are also considered, such as the occurrence of snow at the same time (which would reduce the amount of supercooled water available). An overcast Sc cloud deck is given a higher liquid water content than when breaks are observed. Middle layer clouds were placed at the levels indicated by the moisture and stability structures with the liquid water content values assigned being guided by referenced literature.

Areas of precipitation were then defined. Surface precipitation type and intensity were noted, as well as the reported six-hourly precipitation amounts (an item of data we have found to be frequently missing or inconsistent). These observations determined the low level precipitation water content values. Rain was shown up to the height of the melting level. The "Large Snow" category was carried down to temperatures between -8°C and -12°C, depending upon the intensity of the surface precipitation and local convection. With cumulus clouds present, large snow is carried upward to lower temperatures. If more intense convection is suspected, grauple forms were introduced; this would generally be indicated by the form of the observed surface precipitation.

The "Small Snow" category was carried up to a height with temperatures between -25°C and -30°C. If the moisture pattern so indicated, the top may be indicated also by a stable layer. An Ac layer was often placed at the top of the small snow category if dry air was located above. Above this temperature level, i.e., at lower temperatures, an ice crystal type was suggested by the moisture and stability structure by an observation from the ground or by the texture of the cloud as viewed from the satellite.

3.4 Data Cards

The tabulated liquid water content profile data were transformed to punch cards. Each card contains the following header information:

- Station Location Code
- Day, Month, Year
- Observation Time
- Area Representativeness

The latter parameter was the north-south, east-west dimensions (in kilometers) of an area about a particular station that the analyst determined to be characterized by the generated profile. Each layer of clouds or hydrometeor is then represented by the following:

- Weather Type (precipitation, or cloud type, or clear)
- Top and bottom of layer
- Percentage coverage
- Hydrometeor type (large snow, rain, etc.)
- Liquid water content value

This set of data occupies 36 columns on a standard card. With the header information, each card can carry information for up to three hydrometeor or cloud layers. Additional layers, for the same profile, are carried on additional cards, each with the header information repeated.

Each card was first verified, then run through an error check program provided by AFCRL personnel and modified by ERT. The program checks for gross errors such as height of the top and bottom of the cloud layer, and the possibility of missing data. The resulting data deck for all of the profiles have been turned over to AFCRL.

4. ILLUSTRATIVE EXAMPLES

4.1 Time-Height Cross Section and Satellite Data Analysis

Two cases for the Moscow area (3 and 5 February 1973) have been chosen to illustrate the analysis technique and the end product. The time section analysis for each case is shown, for clarity, in two separate figures, Figures 2 and 3 for 3 February and Figures 6 and 7 for 5 February. Shown in Figures 4 and 5 are, respectively, the DMSP imagery and the nephanalysis for the 3 February case. The corresponding imagery and analysis for the 5 February case are shown in Figures 8 and 9.

Figures 2 and 6 show analyses of the temperature and moisture fields. Superimposed on these analyses are the analyses of stable and unstable layers. The hydrometeor analyses are shown in Figures 3 and 7. Also plotted on these figures are surface weather, wind profiles, and values of the vertical distribution of clouds as given by the AFGWC 3DNEPH. These latter values are noted on the charts at 'ETAC' levels.

It is instructive to compare the cloud fields derived by the analysis technique use of this study with the corresponding cloud fields derived by the 3DNEPH. In Figure 3, at 0300GMT, the time-height cross section analysis indicates a layered cloud deck, 80 to 100 percent coverage, with tops at 1,500m. The corresponding 3DNEPH shows a similar deck, with 85 percent coverage, but with tops at approximately 6,700m. Yet, at 1500 and 2100GMT on both 3 February (Figure 3) and 5 February (Figure 7), there is good agreement between the time section analysis and the 3DNEPH. Part of the discrepancy can be attributed to the fact that the 3DNEPH data do not strictly apply to Moscow, but were extrapolated from two nearby grid points.

4.2 Liquid Water Content Profile Data

The information contained in Tables 3 through 7 is obtained from reading off, every three hours from 00Z to 12Z, the cloud and precipitation parameters from the 5 February case. The height interval covered by a particular condition is indicated in the first column in thousands of feet (a convenient five scale unit). The local area coverage, corresponding roughly to the area visible from a surface observation point, is shown in Column 2. The precipitation types and estimated average water contents are shown in the next two columns. The same sequence is repeated for the cloud water hydrometeors. In the case of cumulus, the important water content values can occur in very restricted areas as these are vertically structured clouds. The number <1/10 is used as an estimate, a value of 1/10 used for this category would give a maximum estimate.

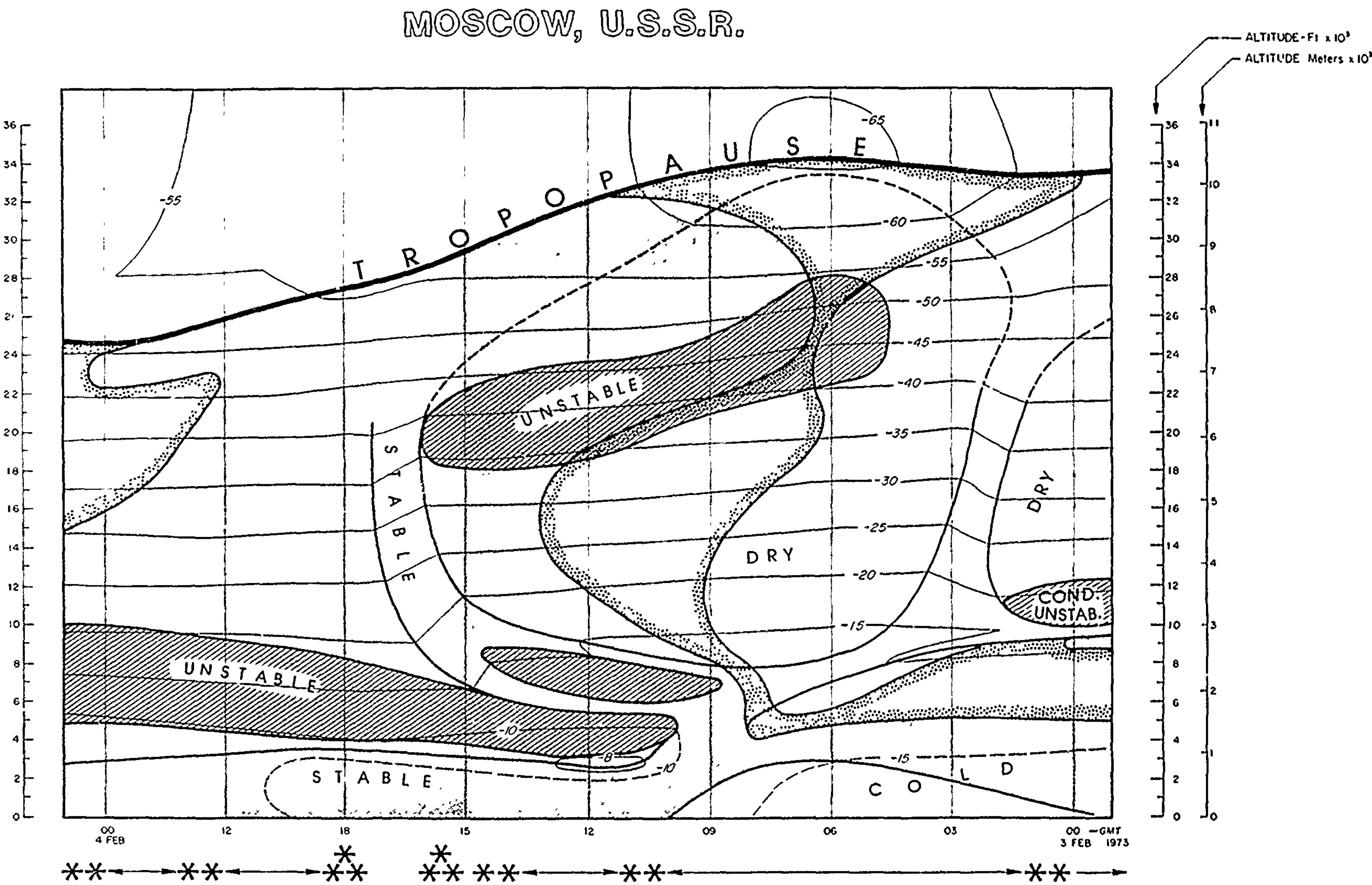

Figure 2 - Time-Height Cross Section Analysis of Temperature, Moisture, and Stability Fields - 3 February 1973, Moscow.

MOSCOW, U.S.S.R.

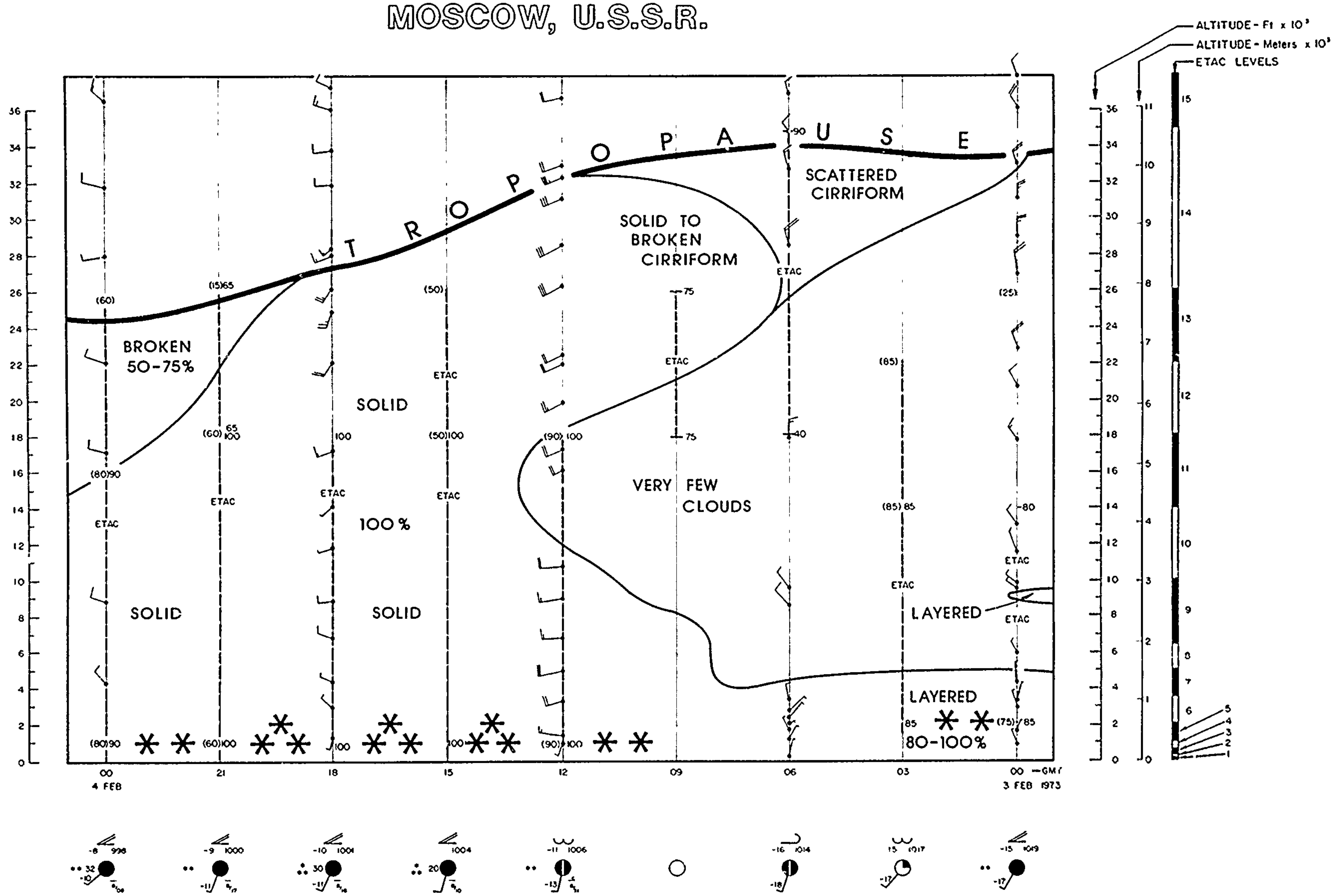

Figure 3 - Time-Height Cross Section Analysis of Cloud and Hydrometeor Fields - 3 February 1973, Moscow.

Figure 4 - DMSP Imagery - 3 February 1973, the Moscow Area.

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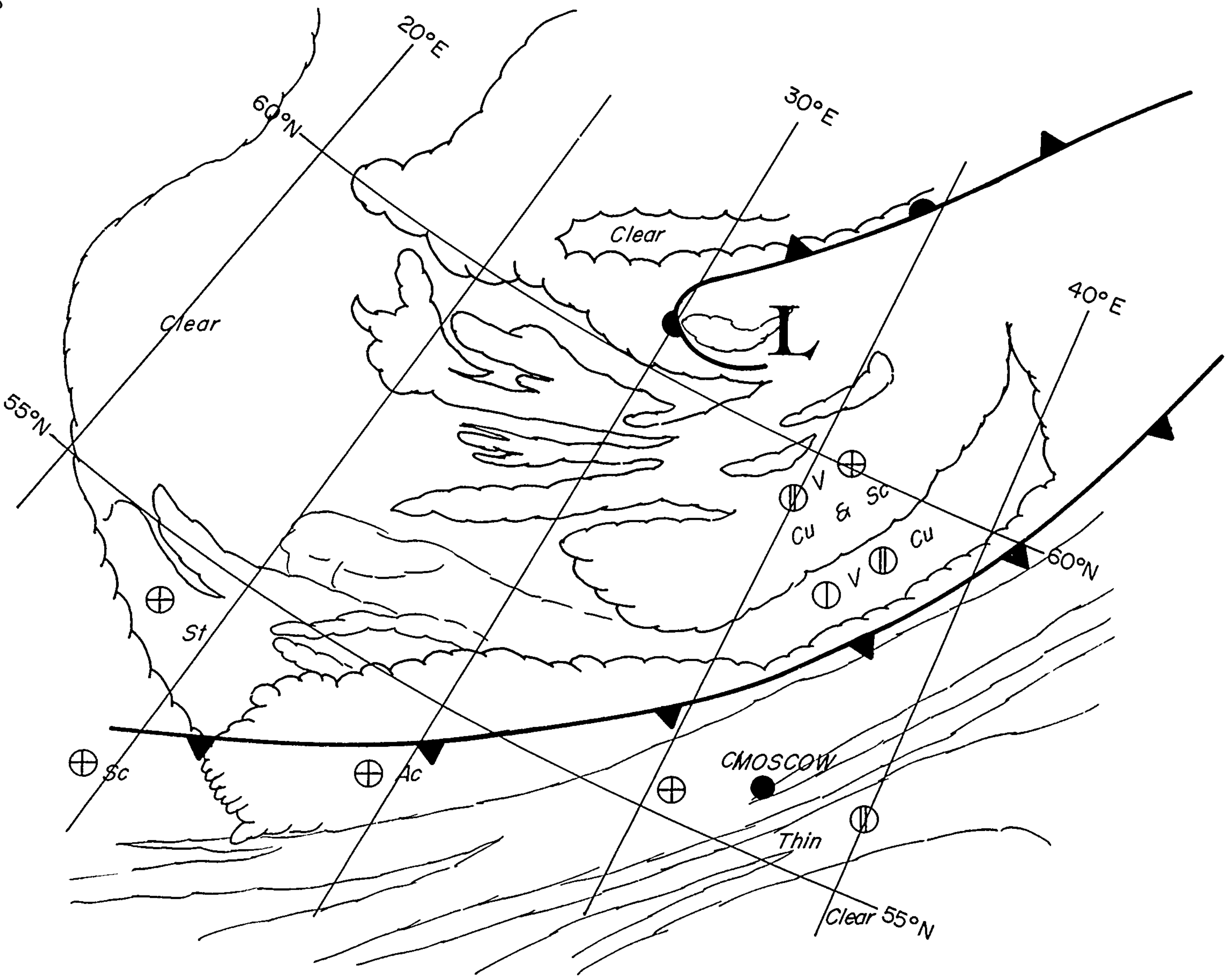

Figure 5 - Nephanalysis - 3 February 1973, the Moscow Area.

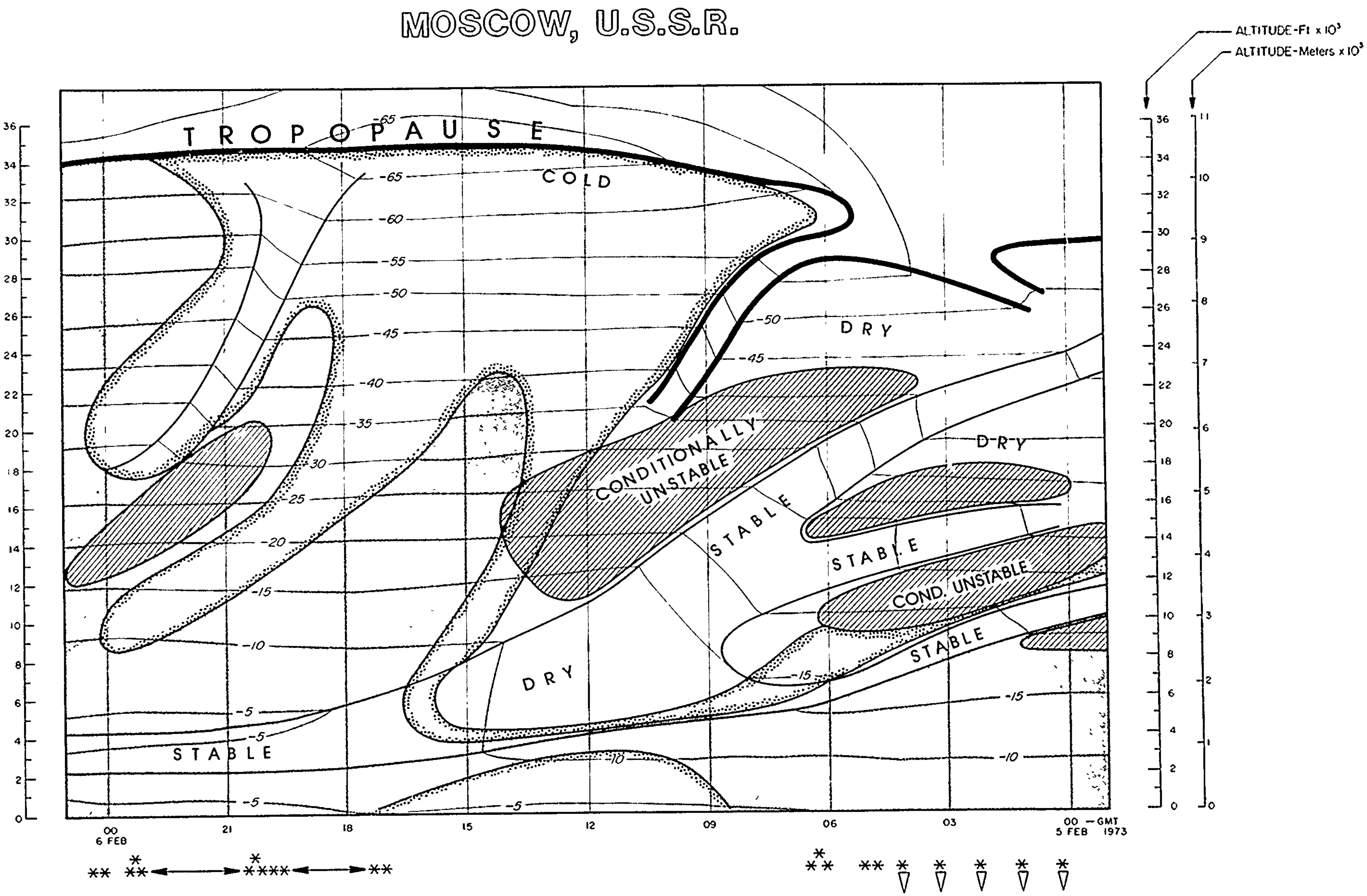

Figure 6 - Time-Height Cross Section Analysis of Temperature, Moisture, and Stability Fields - 5 February 1973, Moscow.

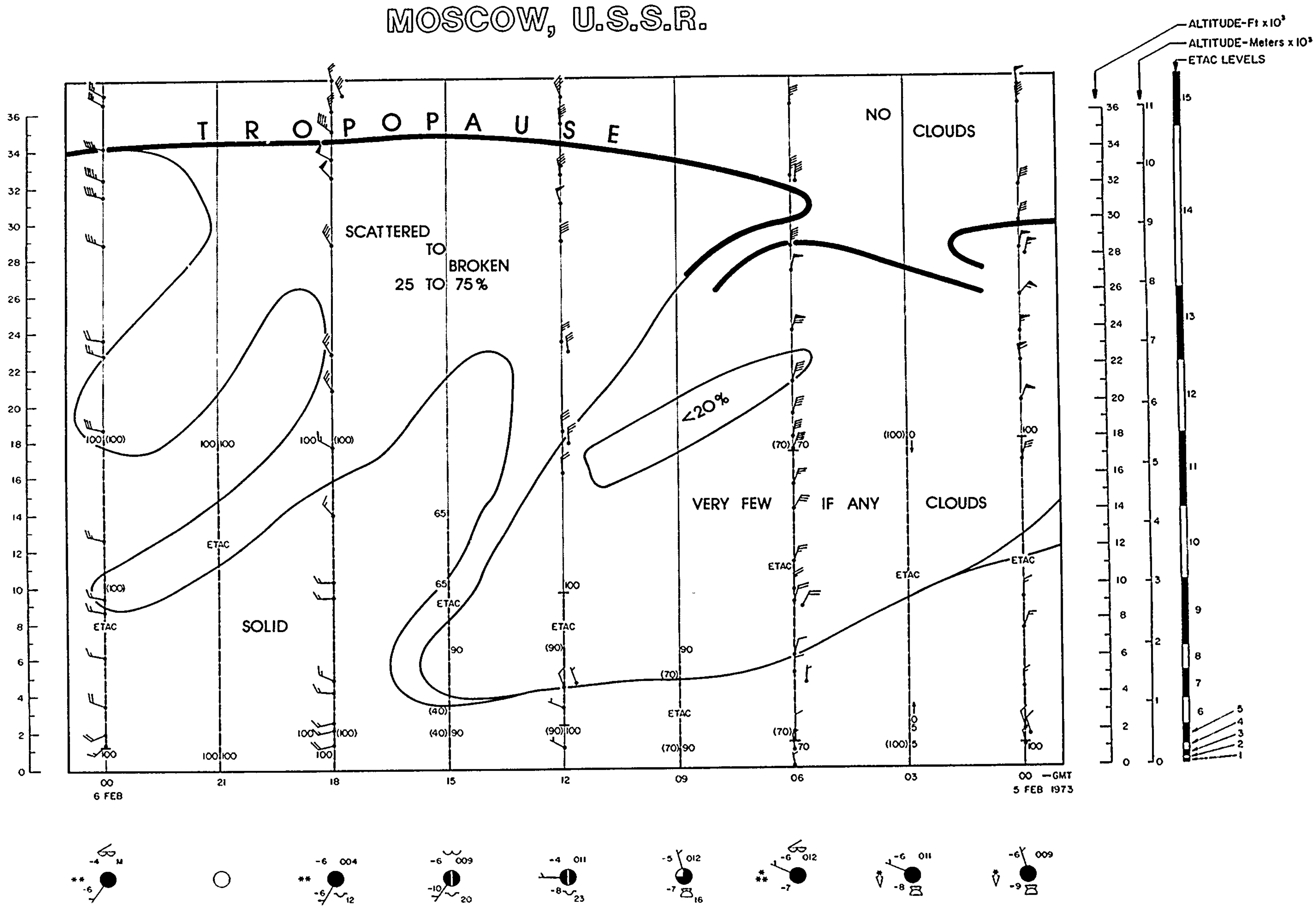

Figure 7 - Time-Height Cross Section Analysis of Cloud and Hydrometeor Fields - 5 February 1973, Moscow.

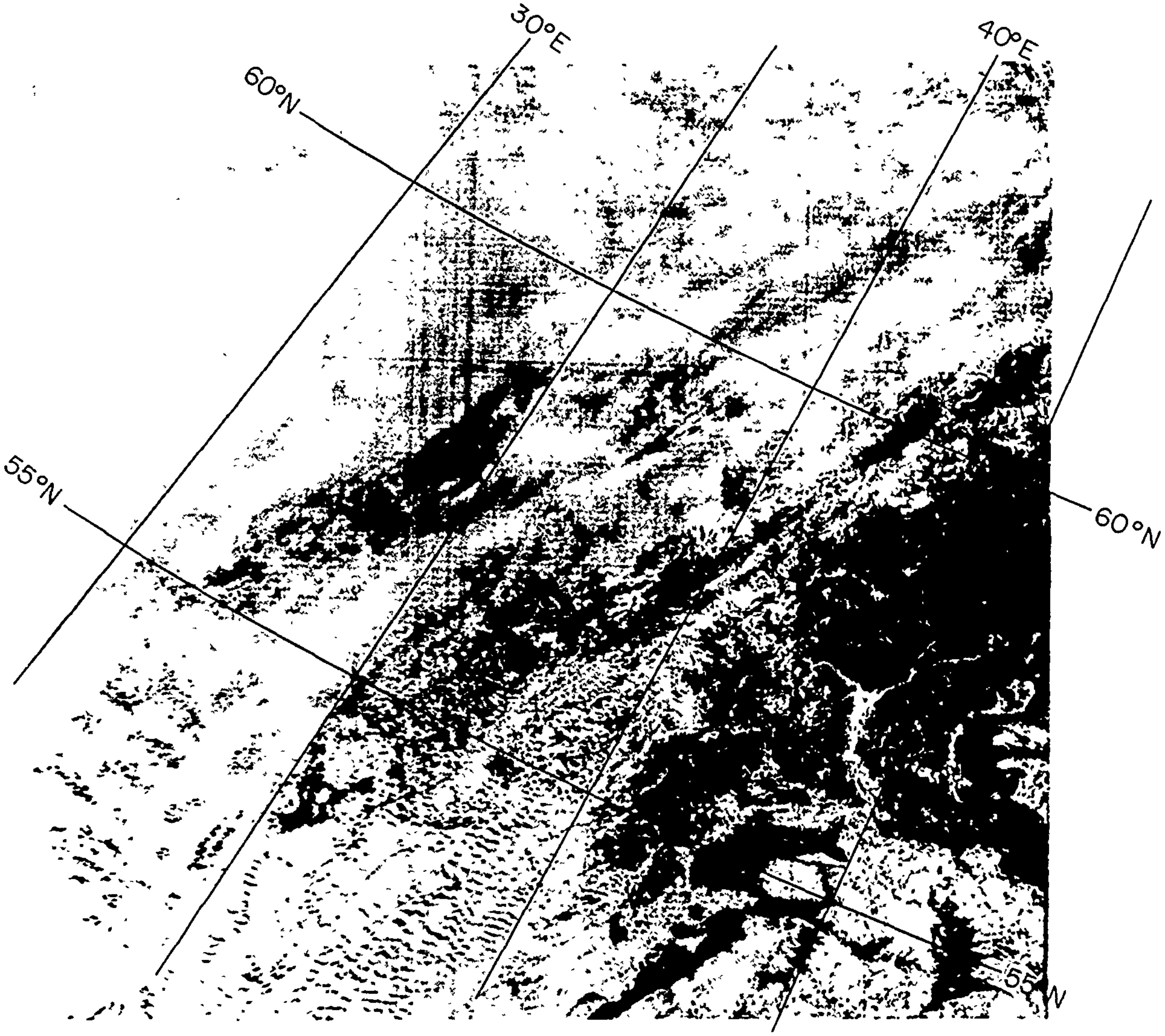

Figure 8 - DMSP Imagery - 5 February 1973, the Moscow Area.

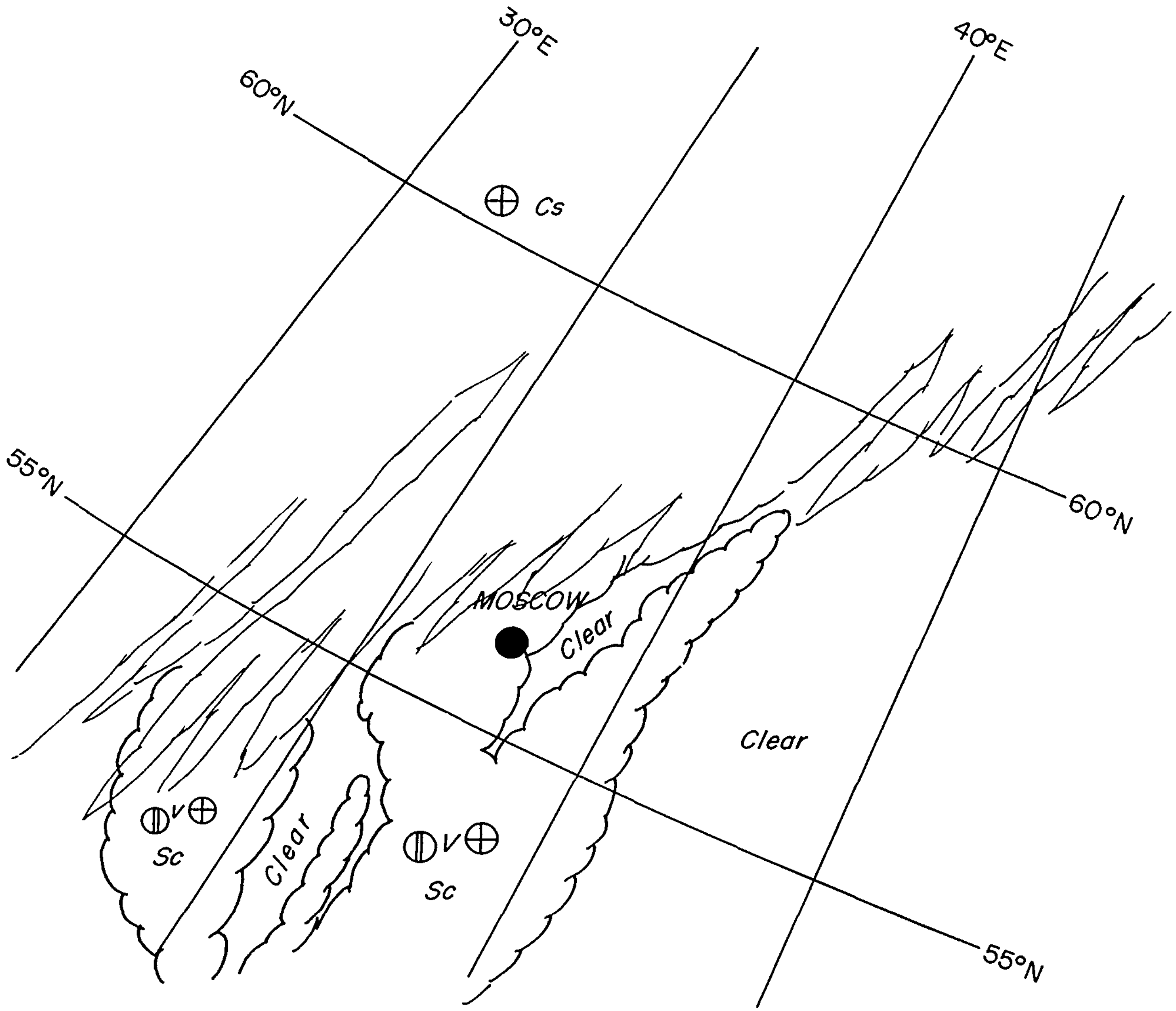

Figure 9 - Nephanalysis - 5 February 1973, the Moscow Area.

Table 3. Liquid Water Content Profile, 5 February 1973, 00Z, Moscow.

LIQUID WATER CONTENT						
LOCATION Moscow (155)		AREA REPRESENTATIVENESS 600 x 250 n.m.			DATE & TIME 5 February 1973 00Z	
ALTITUDE IN THOUSANDS OF FEET	PRECIPITATION			CLOUD		
	COVERAGE	TYPE	PRECIPITATION WATER CONTENT	COVERAGE	TYPE	LIQUID WATER CONTENT
0-3.0	3/10	L.S.	0.01			
0-10.0	1/10	L.S.	0.10			
3-8.5	2/10	L.S.	0.01			
1.7-3.5				10/10	Sc	0.2
3.5-6.0				<1/10	Cu	0.2
6.0-11.0				<1/10	Cu	0.5
11.0-14.5				< 1/10	Cu	0.1
3.5-10.0				3/10	Cu	0.1

Table 4. Liquid Water Content Profile, 5 February 1973, 03Z, Moscow.

LIQUID WATER CONTENT						
LOCATION Moscow (155)			AREA REPRESENTATIVENESS 600 x 250 n.m.			DATE & TIME 5 February 1973 03Z
ALTITUDE IN THOUSANDS OF FEET	PRECIPITATION			CLOUD		
	COVERAGE	TYPE	PRECIPITATION WATER CONTENT	COVERAGE	TYPE	LIQUID WATER CONTENT
0-3.0	3/10	L.S.	0.01			
3.0-6.5	2/10	S.S.	0.01			
0 -8.0	<1/10	L.S.	0.10			
1.6-3.2				10/10	Sc	0.2
3.2-8.0				3/10	Cu	0.1
3.2-6.0				<1/10	Cu	0.2
6.0-9.5				<1/10	Cu	0.5
9.5-13.5				<1/10	Cu	0.1

Table 5. Liquid Water Content Proiile, 5 February 1973, 06Z, Moscow.

LIQUID WATER CONTENT						
LOCATION Moscow (155)		AREA REPRESENTATIVENESS 400 x 50 n.m.			DATE & TIME 5 February 1973 06Z	
ALTITUDE IN THOUSANDS OF FEET	PRECIPITATION			CLOUD		
	COVERAGE	TYPE	PRECIPITATION WATER CONTENT	COVERAGE	TYPE	LIQUID WATER CONTENT
0-3.0	10/10	L.S.	0.10			
3.0-4.5	5/10	S.S.	0.05			
1.9-2.5				10/10	Sc	0.2
2.5-7.0				3/10	Cu	0.2

Table 6. Liquid Water Content Profile, 5 February 1973, 09Z, Moscow.

LIQUID WATER CONTENT

LOCATION	AREA REPRESENTATIVENESS	DATE & TIME
Moscow (155)	200 x 70 n.m.	5 February 1973 09Z

ALTITUDE IN THOUSANDS OF FEET	PRECIPITATION			CLOUD		
	COVERAGE	TYPE	PRECIPITATION WATER CONTENT	COVERAGE	TYPE	LIQUID WATER CONTENT
1.6-3.5				8/10	Sc	0.25
3.5-6.5				<1/10	Cu	0.1

Table 7. Liquid Water Content Profile, 5 February 1973, 12Z, Moscow.

LIQUID WATER CONTENT						
LOCATION: Moscow (155)		AREA REPRESENTATIVENESS: 150 x >600 n.m.			DATE & TIME: 5 February 1973 12Z	
ALTITUDE IN THOUSANDS OF FEET	PRECIPITATION			CLOUD		
	COVERAGE	TYPE	PRECIPITATION WATER CONTENT	COVERAGE	TYPE	LIQUID WATER CONTENT
20.5-29.0	5/10	I.C.	0.005			
2.3-3.5				8/10	Sc	0.25

5. CONCLUSIONS AND RECOMMENDATIONS

A technique, the AFCRL second generation analysis technique, has been developed to derive profiles of liquid water content, which make use of conventional surface and upper air data, and to a lesser extent, satellite data. Since these data are readily available for many areas of the world, the technique has the potential of being a very useful tool to derive climatologies of liquid water content. More importantly, until some new method is developed whereby liquid water content profiles can be obtained routinely (such as with a microwave sounder) and on a global basis, this technique of inference will remain an important practical approach to arrive at this parameter.

The AFCRL second generation analysis technique should be thoroughly evaluated. Basic to the technique are the sets of models (or assumptions). The first of these are the models which relate the vertical distribution of clouds and hydrometeors to the temperature and moisture structure. The second are those which relate the inferred (or observed, if available) cloud and hydrometeor fields to liquid water content. In the present study, the models were developed only for the Eurasian stations under investigation. There is a need, therefore, to develop models for other climatological regions if the technique is to be used globally.

More fundamental, perhaps, is the requirement for extensive measurements to validate even the existing models and to compare the results of this technique with others which employ fewer sets of data. One of the first systematic evaluation of the technique has been conducted by Peirce et al. (1975). They applied the AFCRL II second generation analysis technique to two special sets of data, and compared the derived liquid water content values with those derived using four other approaches: AFCRL first generation model (AFCRL I), Meteorology Research Inc.'s vertical velocity and relative humidity models, and the Smith-Feddes Model. All of these results were then compared with aircraft and/or radar measurements actually taken during the storm or cloud cases. It is their conclusion that an insufficient number of measurements exist at this time to quantitatively evaluate the merits of the AFCRL II second generation analysis technique.

In the light of the potential importance of this approach to global application, it is recommended that programs be developed to validate the models using good aircraft "ground-truth" data.

6. REFERENCES

1. Borovikov, A. M., A. K. Khrgian et al. (1961) Fizika Oblakov (cloud physics) Gidrometeor. Izdatel'stvo, Leningrad (English translation by Israel Program for Scientific Translations, Jerusalem, 1963), (110,121, 382).

2. Browning, K. A., F. F. Hill and C. W. Pardee (1974). Structure and Mechanism of Precipitation and the Effect of Orography in a Wintertime Warm Sector, Quart. J.R.Met Soc., 100 p.320.

3. Coburn, A. R. (1971) Improved Three-Dimensional Nephanalysis, Air Force Global Weather Central Technical Memorandum 71-2.

4. Coburn, A. R. (1970) Three-Dimensional Nephanalysis, Air Force Global Weather Central Technical Memorandum 70-9.

5. Cunningham, R. M. and R. M. Peirce (1974) Environmental Definition Plan Cross Section Analysis. (Unpublished Manuscript.)

6. Danielson, E. F. (1959) The Laminar Structure of the Atmosphere and Its Relationship to the Concept of a Tropopause, Archiv fur Meteorologie, Geophysik und Bioklimatogie A, pp. 293-332.

7. Peirce, R. M, R. W. Lenhard, and B. D. Weiss (1975) Comparison Study of Models Used to Prescribe Hydrometeor Water Content Values, Part I: Preliminary Results, AFCRL-TR-75-0470, Environmental Research Papers, No. 532. Air Force Cambridge Research Laboratories, Hanscom AFB, Massachusetts.

8. Widger, W. K., Jr., P. E. Sherr and C. W. C. Rogers, 1964: Practical Interpretation of Meteorological Satellite Data, Final Report, Contract No. AF 19(638)-2471, ARACON Geophysics Company.